IMAGE PROCESSING METHOD FOR IMPROVING THE CONTRAST IN A DIGITAL DISPLAY PANEL

Field of the invention

The present invention relates to an image processing method for improving the contrast of the video images displayed by a front-projection or a back-projection system. The invention can be applied to video projectors comprising a light valve and a source of illumination for the said valve. The light valve may be of the reflective or transmissive type. The invention is more especially applicable to video projectors comprising a valve of the LCOS, LCD or DLP type.

Background of the invention

Conventional video projectors comprising a light valve are currently capable of generating images having a contrast of between 500 : 1 and 1000 : 1 depending on the valve technology employed. In certain applications, for example digital cinema or top-of-the-range TV sets, this contrast value is not always sufficient. In order to increase this value, a known solution is to modulate the intensity of the light delivered to the valve depending on the contents of the image to be displayed. For example, if the image to be displayed shows a dark scene, the light intensity delivered to the valve is reduced whereas the level of the video signal processed by this same valve is increased in the same proportion. The contrast is now better since the number of bits in the video signal is effectively increased. It is thus possible to achieve a high contrast for the low grey levels which are always critical in TV applications.

One of the known techniques for modulating the light intensity consists in detecting the peak grey level NG_{max} in the image to be displayed and in comparing this with the maximum grey level that can be displayed NG_{MAX} (=255 if the levels use 8-bit encoding):

- if the grey level NG_{max} is below half the grey level NG_{MAX}, the intensity of the light delivered to the valve for the image under consideration is divided by 2 and the amplitude of the video signal delivered to the control circuit of the valve is multiplied by 2,

- if the grey level NG_{max} is above half the grey level NG_{MAX}, the intensity of the light delivered to the valve remains at its peak value and the level of the video signal delivered to the control circuit of the valve remains unchanged.

This technique is illustrated in Figures 1A, 1B and 1C. Figure 1A shows the video signal as a function of time of two images displayed during frames T and T+1, respectively. This signal is delivered to the control circuit of the valve. The voltage of the level NG_{max} of the first image is lower than the voltage of the level $NG_{MAX}/2$ and that of the level NG_{max} of the second image is higher than the voltage of the level $NG_{MAX}/2$. Figure 2B shows the light intensity (luminance) delivered to the valve for each of the two images. According to the process previously defined, it is equal to $L_{max}/2$ for the first image and to L_{max} for the second image. The voltage of the video signal of the first image is therefore multiplied by 2 and that of the second image is kept as it is. The rendering of the video levels of dark images is thus enhanced.

This technique presents many drawbacks. The first one of them is that the image contrast is not enhanced whenever an image pixel exceeds $NG_{MAX}/2$. Accordingly, if the image comprises a single luminous point over a dark background, the image contrast is not increased.

In addition, there is a high current demand (during the transition from $L_{max}/2$ to L_{max} or vice versa) within the light source each time there is a transition from an image having a grey level NG_{max} below $NG_{MAX}/2$ to an image having a grey level NG_{max} higher than $NG_{MAX}/2$ or vice versa. Finally, the device responsible for modulating the light delivered to the valve is not able to switch instantaneously from $L_{max}/2$ to L_{max} or vice versa. Consequently, during the transition, the video signal level cannot be correctly adjusted so that areas of blurred image appear during these transition periods.

The invention proposes an image processing method that allows all or part of the above-mentioned drawbacks to be dealt with.

Summary of the invention

The present invention relates to a method for processing an image displayed by a display device comprising at least one light source and one light valve for transmitting or reflecting all or part of the light produced by the light source, depending on the video signal of the image to be displayed, characterized in that it comprises the following steps:

- applying a compression factor C to the grey levels of the image video signal that are higher than a first threshold value, the said first threshold value being lower than the peak grey level value of the image video signal,

- adjusting the luminance of the light produced by the light source to the luminance value corresponding to the peak grey level of the image after compression, and

- multiplying the video signal delivered to the light valve by an expansion factor D equal to the ratio of the peak grey level of the image before compression to the peak grey level of the image after compression.

Accordingly, the voltage dynamic range of the grey levels above the said first threshold value is compressed and the dynamic range thus gained is reassigned to the whole image signal.

The invention also relates to a device for displaying an image comprising:

- a light source for producing light,
- a light valve for transmitting or reflecting all or part of the light produced by the light source,
- a circuit for controlling the valve, receiving a video signal of the image to be displayed and delivering a control signal to the said valve that is representative of the image to be displayed,

characterized in that the control circuit comprises:

- means for applying a compression factor C to the grey levels of the image video signal that are higher than a first threshold value, the said first threshold value being lower than the peak grey level value of the image video signal,

- means for adjusting the luminance of the light produced by the light source to the luminance value corresponding to the peak grey level of the image after compression,

- means for multiplying the video signal delivered to the light valve by an expansion factor D equal to the ratio of the peak grey level of the image before compression to the peak grey level of the image after compression.

<u>Brief description of the drawings</u>

The invention will be better understood and other features and advantages will become apparent upon reading the description that follows which makes reference to the appended drawings, among which:

- Figures 1A to 1C are timing diagrams illustrating the prior art;
- Figure 2 illustrates the compression of the grey levels above a threshold grey level NG_1 according to the invention;

- Figure 3 is a schematic diagram of a video projector in which the method of the invention could be implemented;
- Figure 4 shows the operations carried out in a control circuit of the video projector in Figure 3;
- Figure 5 shows an example of a calculation of the threshold above which the grey levels of the image are compressed; and
- Figures 6A to 6C, to be compared with Figures 1A to 1C, are timing diagrams illustrating the method of the invention.

Description of preferred embodiments

According to the invention, the grey levels of a restricted number of image pixels (which are the pixels having the highest grey levels in the image) are compressed and the gain in voltage dynamic range is reassigned to the whole image. The compression of the higher grey levels of the image allows the intensity of the light delivered to the light valve to be reduced and the level of the video signal delivered to the valve to then be increased in the same proportion. The contrast of the displayed image can thus be enhanced.

In the remainder of the description, NG_{max} denotes the peak grey level of the pixels of the image to be displayed before compression and NG'_{max} denotes the peak grey level of the pixels of the image to be displayed after compression. In addition, L(NG) denotes the luminance associated with the grey level NG.

According to the invention, the following steps are carried out:

- applying a compression factor C to the grey levels of the image video signal that are higher than a threshold value NG_1 with $NG_1<NG_{max}$;
- adjusting the luminance of the light produced by the light source to the luminance value corresponding to the peak grey level of the image NG'_{max} after compression;
- multiplying the voltage level of the video signal delivered to the light valve by an expansion factor D equal to the ratio of the peak grey level NG_{max} of the image before compression to the peak grey level NG'_{max} of the image after compression.

According to one particular embodiment, the threshold NG_1 is, for example, defined as being the value of the lowest grey level of the X brightest pixels of the image, X being a predefined percentage of the

number of pixels in the image. For an image comprising 1920x1080 pixels, X is, for example, equal to 10%, or 1920x1080/10 pixels. This threshold varies depending on the image to be displayed. An example of calculation of this threshold will be described below with reference to Figure 5. In this embodiment, the threshold NG_1 is higher or lower depending on whether the image to be displayed is brighter or darker. Preferably, the threshold NG_1 is taken as greater than or equal to $\frac{NG_{MAX}}{2}$ where NG_{MAX} is the peak grey level that can be displayed by the panel.

Figure 2 illustrates the application of a compression factor C to the grey levels of an image situated above the threshold NG_1. This figure has an abscissa representing the grey levels of the image before compression and an ordinate representing the grey levels after compression; in this figure $C = \frac{NG_{max} - NG_1}{NG_2 - NG_1}$ where NG_2 corresponds to the peak grey level after compression NG'_{max}.

This compression of the higher grey levels has the effect of reducing the luminance gap between the grey levels above NG_1. The luminance of the light required to display the image is therefore brought down to a value $L(NG'_{max})$ corresponding to the luminance value normally associated with the grey level NG_2 with $NG_1 < NG_2 < NG_{max}$.

The closer the grey level NG_2 is to NG_1, the higher the compression factor is. According to one particular embodiment, the grey level NG_2 can be a function of the threshold NG_1. For example, NG_2 will be taken as equal to the arithmetic mean of NG_1 and NG_{max}, or:

$$NG_2 = \frac{NG_1 + NG_{max}}{2}$$

In this case, the lower the level NG_1 relative to NG_{max} is, the lower will also be the level NG_2 and the lower will be the luminance value $L(NG'_{max}) = L(NG_2)$.

According to another particular embodiment, the factor C can be kept constant whatever the value of NG_1. NG_2 will thus increase in the same proportion as NG_1.

This reduction in the intensity of light delivered to the light valve ($L(NG_2)$ instead of $L(NG_{MAX})$ where NG_{MAX} is the peak grey level that can be displayed by the screen) allows the multiplication of the amplitude of the video signal after compression by an expansion factor equal to $\frac{NG_{MAX}}{NG'_{max}} = \frac{NG_{MAX}}{NG_2}$.

A video projector in which the method of the invention is implemented is illustrated in Figure 3. This projector comprises a light source 1, a light modulator 2 for modulating the intensity of the light produced by the light source 1 as a function of the contents of the image to be displayed, an optical system 3 for sending the light output from the light modulator 2 towards a valve 4 and for sending the image produced by the valve 4 towards a lens system 6. The light modulator 2 and the light valve 4 are controlled by a control circuit 5 which receives the video signal V_{in} of the image to be displayed. It calculates a signal V_{out} to be delivered to the light valve 4 and the luminance value $L(NG'_{max})$ to be delivered to the light modulator 2.

A block diagram indicating the steps performed in the control circuit 6 for implementing the method of the invention is shown in Figure 4.

The control circuit calculates firstly the threshold NG_1. An example of calculation of the threshold NG_1 is given in Figure 5. In this figure, NG denotes a grey level index, B_{NG} denotes the number of pixels having a grey level NG in the image under consideration and A_{NG} denotes a number of pixels such that: $A_{NG} = \sum_{i=NG}^{NG_{max}} B_i$

with $A_{max} = \sum_{i=0}^{NG_{max}} B_i$ (A_{max} is equal to the number of pixels in the image).

In order to define NG_1, starting from the grey level $NG=NG_{max}$, NG is decremented until $A_{NG}>X.A_{max}$ where X is a percentage of the total number of pixels in the image. X is, for example, equal to 10%. NG is thus decremented until $A_{NG}>A_{max}/10$. The threshold NG_1 is then taken as equal to the value NG obtained.

Again referring to Figure 4, the control circuit subsequently calculates the value of the grey level NG_2. It is, for example, equal to the arithmetic mean value of NG_1 and NG_{max} as previously indicated.

The luminance value corresponding to the value normally associated with the value of grey level NG_2 is sent to the light modulator 2. The intensity of light delivered to the valve 4 by the modulator 2 is thus fixed at $L(NG'_{max})$ for this image.

The control circuit 5 also transforms the video signal V_{in} by compressing the grey levels above NG_1 as shown in Figure 3. This modified signal is then multiplied by an expansion factor $D=\frac{NG_{max}}{NG_2}$ in order to reassign the voltage dynamic range unused by the higher levels to the whole video signal. The resulting signal, denoted V_{out}, is delivered to the light valve 4. This transformation of V_{in} to V_{out} thus allows the voltage dynamic range of the grey levels above NG_1 to be compressed to the benefit of the grey levels below NG_1.

The results of the method of the invention are illustrated by the timing diagrams in Figures 6A to 6C which are to be compared with Figures 1A to 1C. Figure 6A is identical to Figure 1A. Figure 6B shows the luminance value of the light delivered to the light valve 4. Since the image displayed during the frame T does not comprise any grey level higher than $\frac{NG_{MAX}}{2}$ (lower limit of NG_1), no grey levels in this image are compressed. The video signal of this image is however multiplied by an expansion factor that is close to 2 in the present case; this is the image of the frame T+1 which does comprise grey levels higher than $\frac{NG_{MAX}}{2}$. The highest grey levels in this image are therefore compressed. The image video signal is multiplied by a smaller expansion factor than that of the T image.

It will be clear to those skilled in the art that other methods of calculating the values NG_1 and NG_2 than those described herein above could be employed in order to implement the method of the invention.